PO.201

Human-Free Offshore Lifting Solutions

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REMS RENEWABLE ENERGY MARINE STRUCTURES

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Abstract

Current offshore wind turbine lifting procedure: - single elements weighing up to hundreds of tonnes and lifted to heights of 100 meters;
- risks to personnel, assets, and the environment during installation and maintenance interventions.

Objectives: - increase safety during offshore lifts;
- solutions for human-free lifting operations.

Methodology: - ranking and selection of most promising concepts based on a multi-criteria decision analysis with 38 survey responses weighting 21 decision criteria;
- logistics: development of a MATLAB-based code for choosing pre-assembly method to optimise installation time, lifted weight, and number of lifts;
- connections: high potential of automated bolting and seafastening solutions to increase safety during transport and speed up the process;
- guidance and control: design and small-scale test of a multidirectional mechanical guiding element in combination with visual guidance by cameras.

Logistics

Existing pre-assembly methods:
- bunny-ear (BE) method (*figure 1a*);
- rotor star (RS) method (*figure 1b*);
- single piece (SP) installation (*figure 1c*);
- tower installation as one piece (1T) or two sections (2T).

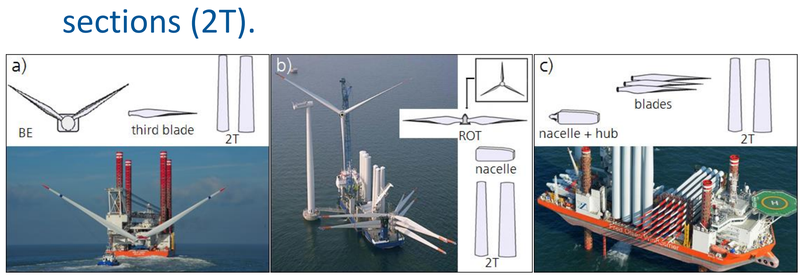

Figure 1. Pre-assembly methods: (a) Bunny-ear [1,2], (b) Rotor star [1,3], (c) Single pieces [1,2].

Pre-assembled wind turbines:
+ require fewer lifts;
+ reduce number of hazardous offshore lifts;
- heavy load with large wind exposed areas;
- increased lifting hazard;
- feasibility constrained by lifting capacities, vessel requirements, and stability limitations for transportation and installation.

Developed MATLAB code (*figure 2*) and GUI:
- find optimal compromise between number of lifts and lifted weights;
- maintain or even decrease installation time.

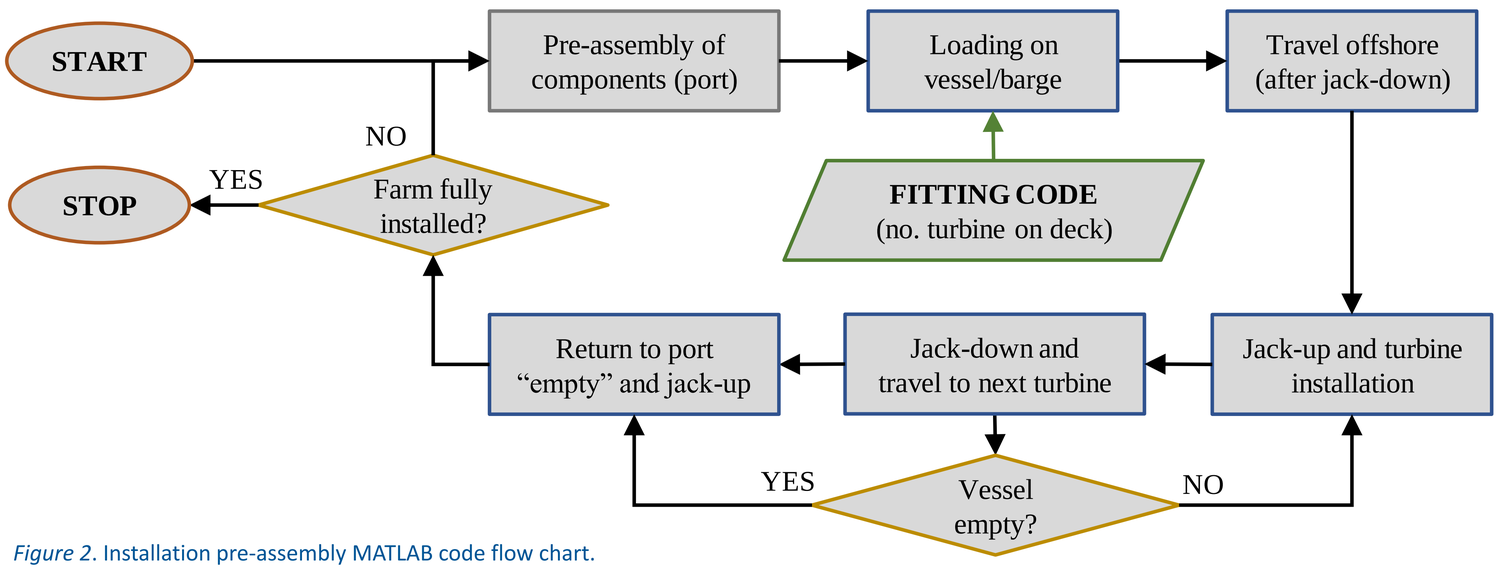

Figure 2. Installation pre-assembly MATLAB code flow chart.

Connections

Commonly used ring-flange connections:
- more than 120 high-strength, pre-stressed bolts of large size (M64 or M72 [4]);
- accurate tightening of pre-assembled bolts.

New connection and seafastening methods:
- friction-based connection solutions [5];
- BLUE Wedge [6] (connection and seafastening);
- hydraulic or internal jack seafastening [7];
- automated bolting systems [8,9].

Enhanced seafastening methods:
- hydraulic seafastening is safer and quicker;
- robot arm employment for automated bolting (*figure 3*), retaining reliability, reducing risk, and increasing speed.

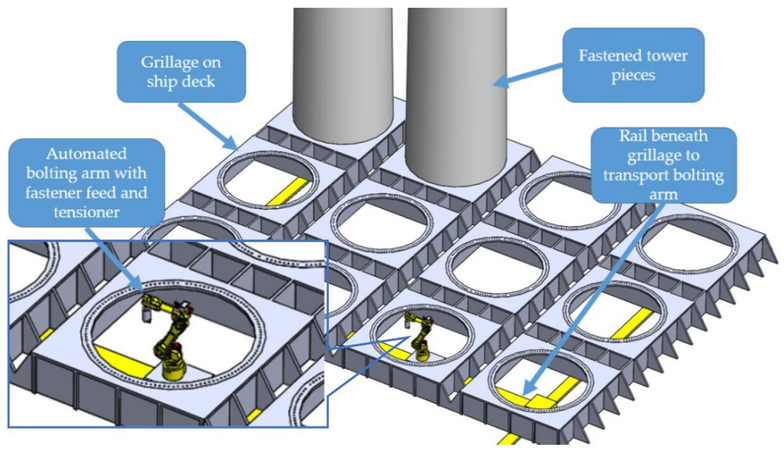

Figure 3. Automated bolted seafastening, concept illustration [10].

Guidance and Control

Global hoisting procedure:
- mostly vertical lift to height;
- use of taglines and remote control.

Final positioning of load on counterpart:
- use of guide pins/rods and socket sections, cones or funnels, and manual guidance;
- proposed solution: **combination of visual and mechanical guiding systems**.

Visual guidance:
- test of different camera configurations;
- best camera setup (*figure 4a*): 3 circumferential standard cameras + 1 central 360°-camera.

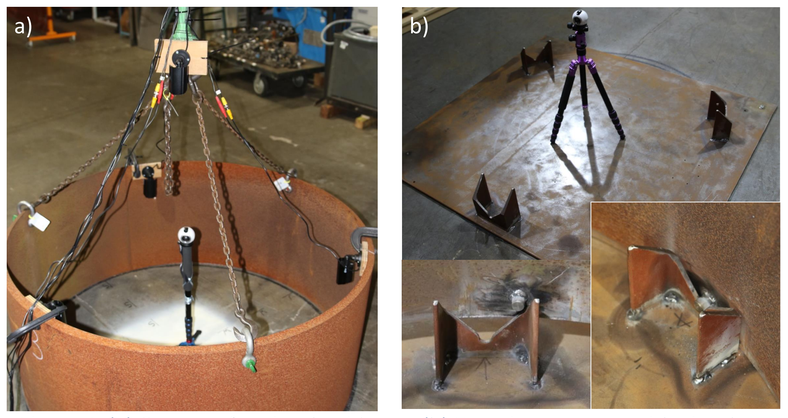

Figure 4. (a) Cameras for visual guidance, (b) Experiment setup with visual and mechanical guiding systems.

Holistic mechanical guiding system (*figure 5*):
- for centralisation and rotational alignment;
- guide rod (on lifted part) + socket section within conical extension (on fixed section);
- removable and reusable.

Figure 5. Holistic mechanical guiding system design.

Small-scale experiments with visual (*figure 4a*) and mechanical guiding systems (*figure 4b*):
- fast lifts with exact positioning;
- cheap auxiliaries will pay for themselves and may even enhance economic gains.

Conclusions

Feasible solutions for human-free offshore lifting operations:
- optimised planning of logistics and turbine installation (MATLAB program);
- novel automated bolted seafastening concept;
- holistic guiding auxiliaries (visual and mechanical) allow human-free lifts.

→ Increased safety with additional economic benefit.

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